Description of a Printing Chronograph.

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About the year 1848 the idea of recording astronomical observations by the use of galvanic electricity was put in successful operation by different individuals. Since that time chronographs of various forms have been constructed for recording in a legible manner, on a moving sheet of paper, the time of any phenomenon observed. The great superiority, in point of accuracy and saving of labour over the old eye-and-ear method formerly used, led to the almost general adoption of the new plan.

During the past ten years the idea of constructing a chronograph which should print with type the time of the observation has been entertained by a number of persons. About five years since Prof. Hilgard, of the U.S. Coast Survey, made a description of an apparatus designed for this purpose, and about the same time Prof. C. A. Young, of Dartmouth College, published a proposed plan for one in *Silliman's Journal of Science.* But, so far as we are informed, the mechanical construction of such an apparatus has not heretofore been attempted by any one.

The construction of a machine which shall carry a type-wheel capable of given impressions, with uniform velocity for a number of hours together, without sensible variation in its motion, is a problem which is not easy of solution.

For a clear understanding of the mechanism elaborate drawings would be necessary, we shall therefore merely give a general account of its construction and peculiarities:—

1st. A system of clock-work carrying a type-wheel with fifty numbers on its rim, revolving once every second; one, two, or parts of two numbers being always printed, so that hundredths of seconds may be indicated. This train is primarily regulated to move uniformly by the Frauenhofer friction-balls, and secondarily by an electro-magnet acting on the fast-moving type-wheel, and controlled by the standard clock. This train is entirely independent, and can be stopped at pleasure without interfering with the other type-wheels.

2nd. A system of clock-work, consisting of two or more shafts, carrying the type-wheels indicating the minutes and seconds. The motion of this train is also governed by an electro-magnet, controlled by the standard clock, operating on an escapement in a manner analogous to the action of an ordinary clock, every motion of the escapement advancing the type one number.

There are three type-wheels, indicating minutes, seconds, and hundredths of seconds. The integer seconds are advanced at every oscillation of the standard pendulum, and the minute at the end of each complete revolution of the seconds-wheel.

Presuming now we have this system of type-wheels in operation, it is necessary to print without disturbing their motion; especially is this true for the fast-moving type-wheel.

After a long series of experiments, during which the fast-moving wheel was detached and stopped in various ways, the impression was finally made from the spring of the hammer only, not allowing the blow to fall directly on the type, but arresting it about half an inch before it reached the top of the type. By this device, which is regarded of the greatest importance, the motion of the type is not disturbed an appreciable amount. Any number of impressions following each other in rapid succession does not disturb the fast-moving wheel the one-hundredth part of a second. By this plan none of the type-wheels are stopped or locked in the act of printing, and records of observations may follow each other as fast as the hammer can be made to deliver the blow.

The printing may be done directly by means of a strong electro-magnet, but the cost and trouble of keeping up a large battery for this purpose led us to do all the work mechanically, only using electricity as the governing power. Accordingly, a heavy running gear was built for raising the hammer, capable in its present form of delivering 2000 blows without winding. This gearing is entirely detached from the hammer when elevated, but is unlocked just before the hammer reaches the type, immediately raising it again. The time consumed for this operation is about three-tenths of a second, allowing therefore observations to follow each other at a minimum interval of one-half second. When the hammer is elevated it is locked by an electro-magnet, the operation of this magnet allowing it to fall and print. As the hammer is acted on by gravity alone, the armature time will be sensibly uniform.

The types are inked by means of small rollers, covered with cloth, resting against their rim, and revolving with the wheel by friction. These rollers require inking every two or three days.

The paper fillet, two inches in width, is wound on a spool holding sixty feet, and drawn between two rollers the same as a Morse Register. Our spool of paper will hold about 1200 observations including the spacing for different objects.

Every time the hammer falls the fillet is advanced one quarter of an inch, by the action of an escapement driven by a weight. The same escapement is also operated by an electro-magnet under the control of the observer, who by pressing a key is able to make spaces of any width between the prints.

To recapitulate, the following are the distinctive features of this mechanism :—

1st. Separate movements for the integer seconds and the hundredths of seconds; 2nd. The method of regulating the hundredths of seconds wheel by an electro-magnet in connection with the standard clock; 3rd. The method of printing double or single numbers without stopping the type-wheels; 4th. The method of striking the blow, indirectly using the spring of the hammer; 5th. The method of elevating and locking the hammer.

The battery power required is about the same as for an ordinary chronograph. Three Grove elements or six Hill's elements

work the two electro-magnets well. A separate battery of about the same size is used for the hammer and fillet magnets.

In point of accuracy this machine leaves nothing to be desired, and is much beyond what we thought possible. From a vast number of experiments, made by recording automatically the beats of the standard clock, both at the middle and end of the oscillation, the mean error for a single print is found to be $0^{s}\cdot013$, equal in this respect to the recording chronograph. The maximum difference in the records of the beats seldom exceeds $0^{s}\cdot03$, and we believe this is as much due to the irregularity in the clock connexion, as in the running of the machine, since the same thing is found in ordinary chronographic records, where the measures are made from second to second.

The saving of time and labour by the use of a printing chronograph is very considerable. At the lowest estimate it does work equivalent to the labour of one person where three are employed at the same time. In our zone-work in former years, when the zone extended two hours in right ascension, it usually required the labour of two persons a whole day to convert the chronograph records into numbers and copy them on the blank forms. With the observations printed this labour is wholly dispensed with, since the "mean" is at once deduced from the printed records.

The machine is readily adjusted to indicate the same numbers as the clock's face, the type being so set as to print zero-hundredths when the pendulum is at its lowest point, where the magnetic circuit is completed.

In the observation of zone-stars or regular transit-work the type may be set to give the integer seconds of mean right ascension, so that the final reduction will always be a small quantity.

The constant use of this mechanism on every day and observing for six months, during which time more than twelve thousand records have been made, enables us to speak with confidence of its success, both as regards correctness in printing and in saving of labour.

Other things being equal it is found that for three observers twice as many observations can be reduced in the same time as when a recording chronograph is employed.

Formulæ for the Calculation of the Orbit of a Double Star. By M. Annibal de Gasparis. (Translation.)

Having reduced by Herschel's method (*Memoirs R.A.S.* vol. v.) positions for six equidistant epochs, let $\varrho_1, \varrho_2 \,..\, \varrho_6$ be the distances and $\phi_1, \phi_2 \,..\, \phi_6$ the angles of position. Denoting by m_{rs} the triangular area described on the plane of projection, and com-